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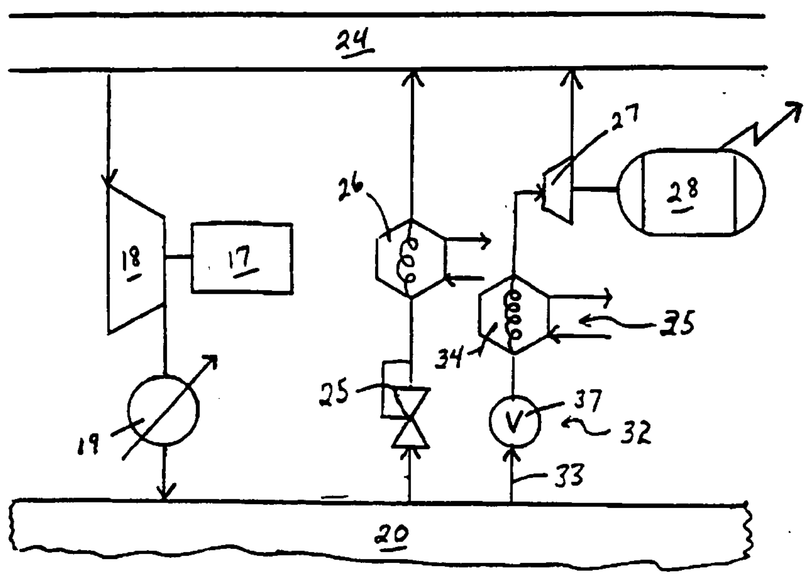
(54) **PROCEDE ET DISPOSITIF DE PRODUCTION D'ENERGIE ELECTRIQUE UTILISANT UN RESERVOIR**

(54) **APPARATUS AND METHOD OF GENERATING ELECTRICAL POWER FROM A RESERVOIR**



(57) Procédé de production d'énergie électrique mettant en oeuvre un réseau de distribution de gaz comportant un réservoir sous haute pression et une canalisation de distribution sous faible pression, ledit procédé consistant à acheminer au moins une partie du gaz sous haute pression contenu dans le réservoir vers une installation satellite produisant de l'électricité. L'installation satellite est constituée d'un dispositif de détente, d'un axe, d'une génératrice reliée à l'axe et d'éléments de commande permettant de régler les valeurs de température, de détente et de débit du gaz comprimé acheminé du réservoir haute pression au réservoir basse pression via le dispositif de détente.

(57) A method of generating electrical power utilizing a gas distribution network comprised of a high pressure gas reservoir and a low pressure delivery pipeline includes the step of directing at least a portion of the high pressure gas within the reservoir through a satellite assembly to generate electrical power. The satellite assembly includes an expander and shaft, an electrical generator operatively associated with the shaft and control members for predeterminely controlling the temperature, the pressure drop and the flow of the compressed gas entering the expander from the high pressure reservoir to the low pressure reservoir.

Abstract

A method of generating electrical power utilizing a gas distribution network comprised of a high pressure gas reservoir and a low pressure delivery pipeline includes the step of directing at least a portion of the high pressure gas within the reservoir through a satellite assembly to generate electrical power. The satellite assembly includes an expander and shaft, an electrical generator operatively associated with the shaft and control members for predeterminely controlling the temperature, the pressure drop and the flow of the compressed gas entering the expander from the high pressure reservoir to the low pressure reservoir.

Background of the Invention

The present invention relates to apparatus and methods of controlling the generation of power for meeting a variable demand wherein a compressed reservoir of air or gas is selectively directed to and through a heat engine to increase the generation of electrical power to satisfy a variable rate demand while minimizing the quantity of heat necessary for such a demand and by eliminating the large quantity of wasted energy in satisfying that demand.

At the present time, the utility industry utilizes an electric transmission and distribution system which, in conjunction with compressed air storage, has attempted to generate power utilizing compressed air storage reservoir. FIG. 1 illustrates the utilization by the electrical utility industry of the generation of power from such a compressed air reservoir. As shown in FIG. 1, a typical electric generating plant or station 11 generates electrical power by burning fuel and generating steam in a boiler 12. This steam is utilized in a turbine 13 which drives the generator 14 to produce electricity. The generated electricity then proceeds to a transformer 15 and onto a transmission line 16. The electricity from the transmission line 16 is then passed through a transformer 15 which delivers the electricity to a motor/generator 17, 28 to power a compressor 18. This motor/generator 17, 28 is selectively coupled to and powers a storage compressor 18 which directs compressed air or gas through an aftercooler 19 to a high pressure reservoir 20 as desired. Thereafter, the compressed gas is withdrawn from the reservoir 20 through a recuperator 21 past a throttle valve 37 and a burner 42 into a turbine 13′, which in turn drives a motor/generator 17, 28 to produce electricity.

As is evident from FIG. 1, the fuel is introduced to the boiler 12 and the turbine 13 drives a generator 14 to produce electricity. The fuel input to this remote generating station 11 is reduced by approximately 70 percent during this generating process, that is, 70 percent of the fuel input to this generating station is lost during the generating process.

The passage of electricity through the transformers 15, the transmission line 16, and the motor/generator 17, 28 to drive the storage compressor 18, results in an additional loss of approximately 12 percent of the fuel energy. The storage compressor 18 is about 70 to 85 percent efficient depending on the difference in the pressures generated in the reservoir. The aftercooler 19 also reduces the efficiency of the system another 2 to 3 percent. Thus, the fuel energy transmitted to the reservoir is reduced by approximately 80 percent and, therefore, less than 20 percent of the fuel energy is delivered to storage for subsequent usage. Accordingly, five units of fuel energy is required to produce one unit of stored energy in the reservoir 20. Additionally, the operation of the motor driven storage compressor 18 and the motor/generator 17, 28 and their functions of compressing air to storage and generating electricity, respectively, requires complex clutch arrangements therebetween. Thus, the unit must be completely shutdown to operate these clutch arrangements which incurs further losses in operating this system. These clutch arrangements limit also the range of generation to the capacity of the motor/generator 17, 28 when so operating and the capacity of the motor/generator in the generating cycle is only about 20 percent more than the motor output capacity. Additionally, the motor/generator 17, 28 driving the storage compressor 18 utilizes expensive electricity for 80 percent of the kilowatt hours produced, with the compressing being done during low system generation, usually at night. Accordingly, the more compressing needed in the system, the higher the cost of electricity to operate this system. Also, the motor/generator 17, 28 is in lock step. Thus, in effect, this prior art compressed energy system must generate electricity twice with substantial fuel losses--once to generate electricity by the electrical generation station 11 and again to generate electricity utilizing the motor/generator 17, 28. Finally, in such prior art processes, a recuperator 21 preferably is inserted between the reservoir 20 and the turbine 13′, which is an uneconomical apparatus and

thermodynamically improper. Preferentially, the air turbine 13′ is divided into two entities, because not all of the fuel is introduced at the entrance of the air turbine but the remainder is introduced along the length of the expander. This structure further creates a diseconomy in using existing compressed air energy systems.

With respect to the process represented by FIG. 1, the compressing by the storage compressor 18 requires a very large compressor, having large energy losses and higher compressor loads, which operates usually at night. Such compressing is limited in time and is intended to increase the amount of generation of other existing units which have very large investment costs. The compressing and generating functions of such plants are in lock-step and each must be shut off when the other is in operation. Also, the requirement of using a motor to drive the storage compressor independent of the generator is prohibitively expensive.

Within the past few years, there have been proposals to deregulate the electric utility industry and open that industry to competition. Accordingly, such industries as the petrochemical industry, the natural gas pipeline industry, and the gas distribution industry now have an incentive to utilize their compressed gas storage reservoirs to somehow generate electricity and power. As shown in FIG. 2, the present practice of the gas industry is illustrated wherein a low pressure pipeline 24 under moderate pressure of between about 300-1200 psi transport compressed gas along its distribution system. Such systems utilize a storage compressor 18 which is coupled with a motor, gas turbine, or other power generating device 17 to drive the storage compressor 18 to compress natural gas through an aftercooler 19 into a reservoir 20. The reservoir 20 pressure may be high, nominally several thousand psi. When it becomes necessary to return the high pressure natural gas from the high pressure reservoir 20 to the low pressure pipeline 24, the gas is directed through a pressure reducing valve 25 and, if necessary, a heater 26 to return the high pressure gas to the low pressure pipeline for

subsequent transmission and/or distribution. The range of such low pressure pipelines may operate within a range of about 15 to 300 psi, for the delivery of gas to the ultimate customer.

It will be seen from the present practice in the transmission, the delivery, and the distribution of natural gas, that the gas industry utilizes compressors, driven either by motors or gas turbines, to facilitate the compression of gas and the delivery of the compressed gas into high pressure reservoirs. However, the gas industry has failed to design and develop apparatus and methods of generating electrical power utilizing these high pressure reservoirs of compressed gas, and instead, the gas industry has merely used pressure reducing valves 25 to decrease the pressure of the gas. Such pressure losses does not recover any of the work spent on compressing the gas to the high pressure reservoir, is wasteful, and environmentally unsound.

Summary of the Invention

The present invention relates to a power generating apparatus having a satellite means or assembly operatively connected to and structurally arranged to communicate with a reservoir of high pressure compressed gas during discharge of the high pressure gas. Such structural arrangements conserve a scare commodity, the gas, by generating electricity within the gas distribution network, either adjacent the high pressure storage reservoir or adjacent the transmission pipelines, or within the distribution systems, itself. Further novel arrangements of the present invention are the design of satellite power generating apparatus which meet continuous, seasonal, and variable demand because the compressed reservoir of gas is selectively directed to the satellite apparatus to increase the generation of power to satisfy an increased demand and to minimize the quantity of the commodity necessary for such demand for electricity.

The novel use of a satellite means or apparatus, expander; generator and controls, to generate electricity in accordance with the present invention from pressurized gas

storage and the generation of power between high pressure compressed gas storage to low pressure delivery pipelines is unknown in the art and takes advantage of the stored energy contained in the gas within the pressurized components of the gas distribution network. Thus, in accordance with the present invention, the entire assemblage of the expander, its heating or cooling source before or after the expander, the generator, the reservoir discharging to the expander, the expander discharge to a point of lower pressure, and controls thereof shall be termed and referred to as a "satellite." Pipelines are also considered as reservoirs containing intermediate pressures and which utilize the satellite in accordance with the present invention.

Also, in accordance with the present invention, a compressed gas energy system is described wherein a gas turbine is operatively connected to a storage compressor which delivers the compressed gas through an aftercooler to a high pressure reservoir. The high pressure reservoir delivers its full pressure to the expander and shaft member of the satellite to generate electrical power.

The primary control of the projected pressure drop through the expander is accomplished by varying the flow of the gas to the expander and shaft member. Thus, the primary control means depends upon the amount of the electrical power generation desired at any particular moment and the specific fluid requirements of the system. A secondary control means may be utilized wherein a heater or cooler is positioned either in the high pressure line entering or, preferably, the low pressure line exiting the expander. The primary control means is directed to satisfy the fluid requirements entering the downstream low pressure reservoir, low pressure pipeline, or atmosphere. If desired, the primary control means uses conventional or normal throttle valves either in the high pressure line entering or the low pressure line exiting the expander. Also, in accordance with the present invention, the generator operates and is controlled in conventional fashion to produce electricity.

Additionally, the satellite assembly in accordance with the present invention is structurally arranged to overcome the problems of existing designs of the electrical industry, wherein the power generation of the utility at night is used to store compressed air. Accordingly, because the motor/generator aspect of existing plants generate electricity twice with very high irreversible losses, a very high cost electricity is produced, which presents other unsolved problems which the present invention solves.

Also, in accordance with the present invention, the satellite assembly has a unique advantage over conventional electric utility arrangements because, when operated correctly, the satellite assembly possesses the most rapid-start engine possible and is the most economical method of generating electricity to meet emergencies. As is known in the art, the electrical power generation equipment in the electrical utility industry requires from 3 to as high as 24 hours to begin generating electrical power. Thus, conventional electric generating plants are required to be ready and running at all times and are, known in the industry as "spinning reserve." Each electrical utility must have generating units in operation which provide a spinning reserve available to recover a 15 percent loss or the loss resulting from the shutdown of the largest unit on the system.

Also, the present invention utilizes the untapped source of high pressure gas in a reservoir which effectively cuts the cost, and reduces the cost of processing the gas from the high pressure reservoir to the low pressure pipeline by generating electrical peaking power while readily meeting environmental restrictions. Moreover, the present invention discloses apparatus and controls that are necessary for converting compressed gas storage in the gas transmission delivery industry to electrical power.

Importantly, the gas transmission industry is the owner of many storage reservoirs of all types and sizes. The pipelines themselves are large reservoirs and may have practical pressures of more than 4,000 psi. These pipelines

are generally usable and available in such high pressures and with pressures which vary between about 300 to 1200 psi. In the gas transmission industry, cycling from storage may be continuous, hourly, seasonally, or even semi-annually. Finally, the gas industry uses a tolerance which is referred to as "packing," which is the pressure used to provide an incremental increase in pressure for later use from the reservoir or pipeline. For example, if the reservoir pressure is increased and the lower pressure gas pipeline supplied to the city is decreased, the incremental change in pressure may be doubled and more generation of electrical power is possible during peak hours of operation in accordance with the present invention.

The satellite assembly for generating electrical power within a gas distribution network in accordance with the present invention includes an expander and shaft member, an electrical generator member operatively associated or coupled to the shaft and a control means for predeterminely controlling the pressure drop and flow of the compressed gas from a high pressure reservoir through the expander. The control means may include a throttle valve member operatively connected between the high pressure gas reservoir and the expander. Alternatively, the control means may include a throttle valve member operatively connected between the expander and the lower pressure pipeline. The method of generating electrical power utilizing a gas distribution network having a high pressure gas reservoir and a low pressure delivery pipeline includes the step of directing at least a portion of the high pressure gas contained within the high pressure reservoir through the satellite assembly to generate electrical power.

The present invention further consists of certain novel features, devices, and structural details hereinafter fully described, and illustrated in the accompanying drawings and particularly pointed out in the appended claims, it being

understood that various changes and details may be made without departing from the spirit, or sacrificing any of the advantages of the present invention.

Description of the Drawings

For the purpose of facilitating and understanding the present invention, illustrated in the accompanying drawings are the preferred embodiments of the present invention thereof, from an inspection of which, when considered in connection with the following description, the invention, its operation, and many of its advantages, will be readily understood and appreciated.

FIG. 1 is a schematic diagram illustrating the components of a conventional electric transmission and distribution system which generates power from a compressed gas storage reservoir, in accordance with the prior art;

FIG. 2 is a schematic diagram illustrating the apparatus and components of the gas storage and distribution system in accordance with the prior art;

FIG. 3 is a schematic diagram illustrating the apparatus and method of generating electrical power utilizing a satellite assembly system in accordance with one embodiment of the present invention;

FIG. 4 is a schematic diagram illustrating a portable apparatus and method of generating electrical power utilizing a satellite assembly system in accordance with a further embodiment of the present invention;

FIG. 5 is a schematic diagram illustrating a simple satellite assembly in accordance with another embodiment of the present invention;

FIG. 6 is a schematic diagram of a satellite assembly in accordance with a further embodiment of the present invention;

FIG. 7 is a schematic diagram of a satellite assembly in accordance with a further embodiment of the present invention;

FIG. 8 is a schematic diagram of satellite assembly in accordance with a further embodiment of the present invention;

FIG. 9 is a schematic diagram of a satellite assembly which controls the temperatures leaving the expander to provide heating and/or cooling of the commodity gas in accordance with a further embodiment of the present invention;

FIG. 10, is a schematic diagram illustrating the throttling or controlling the flow of gas through the satellite generator in accordance with one embodiment of the present invention;

FIG. 11, is a schematic diagram illustrating a further embodiment of controlling the flow of gas through the satellite generator in accordance with the present invention; and

FIG. 12, is a schematic drawing illustrating a further embodiment of controlling the flow of gas through the satellite assembly in accordance with the present invention.

Detailed Description

For understanding the present invention, reference is made to the drawings wherein like numerals have been used throughout the several views to designate the same or similar parts. In FIG. 2, a compressed gas energy storage system is described wherein a gas turbine or motor 17 is operatively connected to a storage compressor 18 which delivers the compressed air or gas through an aftercooler 19 to a high pressure reservoir 20. The high pressure reservoir 20 nominally may have a pressure of thousands of psi. Although not always necessary, it is generally preferred that the output from the storage compressor 18 into the reservoir requires an aftercooler 19 to be inserted to control the temperature to the reservoir. Additionally, as illustrated in FIG. 2, the present practice of the natural gas distribution industry is that when it becomes necessary to return the high pressure natural gas from the reservoir to the low pressure pipeline 24, the gas is generally directed through a pressure reducing valve 25. If necessary, a heater 26 may be used to

return the high pressure gas to the low pressure pipeline 24. These present practices discard the work expanded in compressing the gas to the high pressure reservoir.

In accordance with the present invention, an expander and shaft member 27 is operatively coupled with a generator 28 in the gas distribution industry network which utilizes the compressed high pressure gas storage reservoir and the flow thereof back to the low pressure pipeline 24, as shown in FIG. 3. This utilization permits the generation of electrical power during the return of the high pressure compressed gas in the reservoir 20 to the low pressure delivery pipeline 24 by utilizing the stored pressure contained in the high pressure reservoir to generate electricity. In accordance with the present invention, the entire assembly of the throttle valve member 37, the expander and shaft member 27, the generator member 28, and suitable control means, which utilizes the energy within the high pressure reservoir 20, shall be referred to as a satellite assembly 30, as shown in FIG. 5.

A primary control means 32 depends upon the amount of electrical power generation desired at any particular time and the specific fluid requirements and limits of the system. Accordingly, a primary and a secondary control means may be utilized to direct and satisfy the fluid requirements entering the downstream pipeline or atmosphere. One secondary control means 35 for controlling the temperature within and leaving the expander 27 is accomplished by varying the temperature of the gas entering the expander. This secondary control means 35 is, preferably, a heater/cooler 34 which is inserted in the line exiting the expander but which may be inserted in the high pressure line 33 exiting the reservoir 30 for controlling the temperature through the expander 27. The cooler/heater 34 may be positioned in the high pressure line 33 to control the projected temperatures through the expander 27, as shown in FIG. 3, or the heater/cooler 34 may be positioned downstream of the expander to control the projected temperatures exiting the expander, as shown in FIG. 7 in the dotted line as 34′.

Additionally, as shown in FIG. 3 and disclosed above, a motor or turbine 17 drives a storage compressor 18 which directs the compressed gas through an aftercooler 19 to the high pressure reservoir 20. Thus, the only equipment necessary to generate electrical power utilizing the flow of gas from a high pressure reservoir to a low pressure pipeline is the insertion of a satellite assembly 30, having an expander and shaft member and a generator member to the system, with proper controls, as shown in FIG. 3. A fully integrated compressed gas storage facility requires an operational compressing sub-assembly, which is an investment wherein each individual compressing station utilizes the equivalence of 1 to 10 megawatts which would consume about one percent of a electric generating unit in accordance with the present invention. There may be larger installations up to 1000 megawatts.

A primary control means 32 of the satellite assembly is provided and includes an conventional or normal throttle valve 37 which controls the amount of high pressure gas into the expander 27, as shown in FIG. 3. The large reservoirs and the gas distribution pipelines, which also may be considered large reservoirs, operate at practical pressures of between about 300 to 500 psi. These high pressures can be and are varied to and from the reservoir and the pipeline and such a distribution system is designed to handle an expensive commodity, natural gas. At the present time the gas industry provides cycles of operation to and from storage which may be continuous, hourly, seasonally, or even semi-annually with a temperature range which is varied. The high pressure created in the reservoir of compressed gas creates a high density and allows more pounds to flow through the same size expander to increase the generation of electricity as required. When the generation of electricity produced by a satellite in accordance with the present invention is utilized during the daytime operation, the generator output may be enhanced by predetermined packing of the compressed gas into the high pressure reservoir 20. Also, as shown in FIG. 3, a pressure

reducing valve 25 is inserted into the high pressure line 33 that extends from the high pressure reservoir 20 to the low pressure pipeline 24. Under normal and customary operations in the gas distribution industry, the pressure reducing valve 25 is utilized to reduce the pressure of the compressed gas exiting the reservoir 20 and entering the low pressure pipeline 24.

As shown in FIG. 3, in accordance with the present invention, it will normally be impractical to attempt to have the flow of gas through the expander and shaft 27 and into the low pressure pipeline 24 be identical to that flow of gas desired for customers purchasing natural gas from the low pressure pipeline. For that reason, a flow of gas through pressure reducing valve 25 may be added to the flow of gas through the satellite means or assembly 30. It can also be added through remote stations and their pressure reducing valves. It will often be desirable to have a simultaneous flow of gas through the compressor 18 into the high pressure reservoir 20 and a flow of gas out of the high pressure reservoir into the expander or shaft 27 and through a low pressure line 31 into the low pressure pipeline 24. The primary control of the operation of the expander and shaft 27 will, preferably, be in accordance with FIGS. 3-11 wherein a throttle valve 37 is positioned in the line entering the expander. However, in the alternative, it may be desirable to have the flow of gas directed through the primary control means or throttle valve 37 positioned in the line preferably bypassing or exiting the expander. Exiting the expander or shaft 27 is a low pressure line 38 which directs the flow of gas into the low pressure pipeline 24. If, when the pressure drop is too large for the gas going through the expander or shaft 27, the temperature of the gas may become too low for the downstream apparatus or the low pressure exit line 38 and low pressure pipeline 24. Under such a condition, the flow of gas may be controlled by the pressure reducing valve 25 and by bypassing the flow of gas through the expander or shaft 27 to produce electricity.

When the pressure drop of the compressed gas is too large through the satellite assembly 30, the temperature may become to low for the downstream piping 38 and 24. Although some flow of gas pressure in the low pressure pipeline 24 will assist in correcting the temperature loss due to the pressure drop through the expander 27, because the throttling effect of the pressure reducing valve 25 will not provide any loss in temperature, it will provide some heating of the satellite discharge. When the flow of the pipeline 24 is larger with respect to the gas satellite flow, this need will be minimized and/or eliminated. This may be true for any installation where a small satellite assembly 30 is utilized and the economics and capital risk of the equipment dictates. Thus, the operation of the satellite assembly 30 in conjunction with the existing gas distribution industry, as shown in FIG. 2, may result in the parallel operation of the satellite and the throttling equipment of the compression station. The satellite assembly generally shown in FIG. 3 prevents the loss of waste energy within the natural gas industry and provides a satellite assembly which can readily operate at nearly 100 percent capacity depending on the pressure and flow in the low pressure pipeline. When there exists sufficient flow and pressure within the low pressure pipeline 24, no heater/cooler 34 is necessary when the gas is directed through the high pressure line 33 into the expander.

In FIG. 4, the novel satellite assembly 30 is disclosed and involves the utilization of portable satellite assemblies 31 which are transportable and movable during the seasons for providing electrical power. These portable satellite assemblies 31 provide fast start-up capabilities and may be utilized to generate electrical power as well as directing the excess compressed gas exiting the satellite through low pressure exiting line 38 to be directed to a customer or ultimate customer 44 for ultimate consumption. Thus, these portable satellite generators may be tied into any location so long as there is a source of high pressure gas from a high pressure reservoir or pipeline 20 which gas may be

directed through the expander 27 to generate electricity, as desired. Although FIG. 4 does not include a throttle valve 37 and a heater/cooler 34, such devices may be necessary in directing the gas from the high pressure pipeline or reservoir through the satellite generator 31. However, the line 38 exiting the expander 27 represents the delivery of gas to a customer 40.

FIGS. 5-8 describe the various arrangements of the satellite generating apparatus 30 which will provide services in addition to pressure reduction and the generation of electricity. For example, in FIG. 5, the simplest satellite assembly 30 is comprised of an expander 27, a generator 28, and a throttle valve 37 as the control means, as enclosed by the dotted lines in FIG 5. Such a satellite assembly is of low cost and may generate more than 10 megawatts and may be configured in a small portable vehicle. Also, it is assumed that no special heat input apparatus or heater as a second control means 35 or throttle valves as the first control means 32 are generally necessary only to start and shutdown the satellite assembly 30. Thus, the compressed gas from the high pressure reservoir 20 is directed through a high pressure line 33 into the expander 27 to drive the generator 28 at a nearly 100 percent capacity factor depending on the resistance to flow in the low pressure pipeline 24. As noted above, no heater 34 is necessary, the capital costs are very low, and the energy costs are minimized.

FIG. 6 is an example of a satellite assembly 30 which contains a component of a gas turbine, similar to an expander 27 that the electric utility industry would use with pressurized air from a high pressure reservoir 20. A burner 42 is provided in the high pressure line 33, the burner consuming oil or gas. The combustion gases leaving the gas expander turbine are exhausted to atmosphere. The apparatus of FIG. 6, cannot be used to process natural gas or other combustible commodities but may be utilized to work with a compressed air storage facility.

FIG. 7 is similar to the apparatus described in FIG. 6 except that the satellite assembly 30 can process both air and commodity gases. If air is used, the apparatus is similar in construction to that shown in FIG. 6, with the air being exhausted to the atmosphere. When a commodity gas is utilized the gas will be directed to and through the high pressure line 33 and the heater 34 for entry into the expander 27 for subsequent direction into the low pressure pipeline 24 or to the ultimate customer. Importantly, the heater 34 may be positioned on the entry side of the expander or on the exit side of the expander, as shown on the dotted line 34′.

The apparatus shown in FIG. 8 is similar to the apparatus of the satellite assembly 30 shown in FIG. 5 with the exception that a cooler 44 is placed such that the exhaust from the expander 27 is directed through the cooler. Thus, such an apparatus for a large customer electrical generator will produce both electricity as well as provide air conditioning or refrigeration to cool a customer's facility. As set forth above, the high pressure of the gas at the inlet of the expander, which was wasted previously, produces enough energy to satisfy two processes downstream of the expander, that is, cooling and the delivery of low pressure gas to the customer.

Although these satellite assemblies are generally to be of a small scale to match the network of the gas industry, both the electrical and gas fields require some large facilities of about 1000 megawatts. District cooling is one of the fields that larger satellites might serve profitable. The operation of the larger satellite assemblies may be reversed in that compressed or pressurized air may be injected at the site of the burner and the mixture of combustible gas and pressurized air may have the same effect upon the satellite assembly, as disclosed in FIG. 6.

The satellite assembly 30 illustrated in FIG. 9 could be called a seasonal satellite because the configuration controls the temperature leaving the expander 27 so that circulation through the heater/cooler 34 maintains a

comfortable temperature within a large building or enclosure. Thus, depending upon the desired temperature leaving the expander 27, the output of the satellite assembly 30 and the heater/cooler 34 may be directed to a customer as desired.

The usage of certain gases may allow gaseous operation at minus 200 to 300° F in the field of cryogenics. Certain provisions can be made to control the effects of impurities. The gas network does remove many and much of the impurities before shipping so that the customers generally receive a clean commodity. The techniques are well known within the community of gas processing engineers and the requirements are not extreme.

In accordance with the present invention, the utilization of a first control means, such as throttle valve 37, may be positioned before and after the expander to predeterminely control the pressure drop within the expander. A second control means such as a heater/cooler 34 may be used to control the temperature. Preferably, the temperature of the gas leaving the gas expander 27 is controlled instead of the temperature of the gas entering the gas expander.

As illustrated in FIGS. 10-12, the satellite assembly 30 is comprised of an expander and shaft 27, an electrical generator or other power receiving means 28 operatively associated with the shaft, controlled throttle valves 37, block valves 46 for maintenance, as well as high pressure piping 33 and low pressure piping 24. As desired, a pressure measurement and control device or member 47 is associated with the high pressure piping to measure the pressure of the gas exiting the high pressure reservoir 20.

Specifically, in FIG. 10, the throttle valve 37 at the inlet to the expander 27 is the usual method utilized for reducing flow through the expander. Although, it is the least efficient control means, it is the cheapest investment in reducing the flow through the expander. Preferably, the configured operation of FIG. 10 is utilized only during start-up of the satellite to satisfy the demand for electricity. However, the utilization of throttle valve 37 may be used

before entry of the gas to the expander to control the flow, pressure, and temperature of the gas within the controlled network. The satellite assembly 30 is generally configured from between 1 to 10 megawatts and will continue to use the existing throttling valve 37 within the gas storage network to reduce some of the pressure associated with the expander and satellite assembly. Moreover, it is preferred that the use of heat exchangers be avoided wherever possible to reduce the cost of the installation and to maintain simplicity of design.

FIG. 11 illustrates the use of a second control means or control throttling valve 37′ which throttles the high pressure flow through a bypass line 33′ for discharging to a point intermediate of the expander. Such a configuration reheats the commodity gas flow in the lower portion of the expander. In this manner, the expander efficiency is improved over a set pressure drop, with the net result of extending the range of the generator output by achieving a lower temperature drop through the expander. As further shown in FIG. 11, the bypass high pressure line 33′ includes pressure measurement and control means 47. The range of this second method of controlling the flow of gas through the operating satellite improves the efficiency of the expander over a set pressure drop. Block valves 46 are needed to isolate the expander for maintenance purposes.

FIG. 12 illustrates a further method of control of the pressure drop through an expander by installing a throttling or control valve 37 at the exit of the expander. This structure overcomes the problem of rapidly opening a throttling valve at the entrance of a expander which develops thermal shock to the apparatus. Thus, utilizing a throttling or control valve 37 at the exit of the expander reduces thermal shock and provides a start-up power generating machine on both gas and electric systems that is rapid and efficient. As shown in FIG. 12, block valves 46 are positioned in the system on the high pressure line 33 entering the expander 27 and on the line 38 leading to the low pressure pipeline 24 for maintenance of the network.

In accordance with the control methods set forth above, the advantages of utilizing a satellite electrical generating apparatus between a high pressure source of gas and a low pressure pipeline is the conservation of wasted energy. Additionally, the utilization of a satellite between a high pressure reservoir and a low pressure pipeline results in the conservation of premium fuels which substantially reduces atmospheric pollution generally and eliminates atmospheric pollution at the satellite assembly. The present invention provides also for a unique method and apparatus for generating electrical power which eliminates the fuel costs, which possesses low capital costs, which enjoys low operating costs and low maintenance costs.

Although the present invention has been described with reference to the preferred embodiments, those skilled in the art will recognize that changes may be made in form and detail without departing from the spirit and scope of the invention.

I Claim:

1. A method of generating electrical power utilizing a gas distribution network comprised of a high pressure gas reservoir and a low pressure delivery pipeline includes the step of directing at least a portion of the high pressure gas within the reservoir through a satellite assembly to generate electrical power.

2. The method of generating electrical power in accordance with claim 1, wherein said satellite assembly includes an expander and shaft member.

3. The method of generating electrical power in accordance with claim 2, wherein said satellite assembly further includes a generator operatively coupled to said shaft to be driven thereby.

4. The method of generating electrical power in accordance with claim 3, wherein said satellite assembly further includes control means for predeterminely controlling the stored pressure of the gas entering said expander and shaft member to generate electrical power.

5. The method of generating electrical power in accordance with claim 4, wherein said control means includes a throttle valve member operatively connected between said high pressure gas reservoir and said low pressure delivery pipeline.

6. The method of generating electrical power in accordance with claim 4, wherein said control means includes a throttle valve member operatively connected between said high pressure gas reservoir and said expander and shaft member.

7. The method of generating electrical power in accordance with claim 1, wherein the capacity of said satellite assembly is 1000 megawatts or less.

8. The method of generating electrical power in accordance with claim 1, wherein the capacity of said satellite assembly is between about 1 to 10 megawatts.

9. The method of generating electrical power in accordance with claim 4, further including the step of positioning a cooler member in the line exiting said expander to provide refrigeration or district cooling.

10. A satellite assembly for generating electrical power within a gas distribution network having a first reservoir of gas at a pressure greater than gas within a second delivery pipeline, including in combination an expander and shaft, an electrical generator operatively associated with said shaft, and control means for predeterminely controlling the temperature and pressure drop and flow of the compressed gas entering the expander from the first reservoir to said second reservoir.

11. The satellite assembly in accordance with claim 10, wherein said control means includes a throttle valve member operatively connected between the first reservoir and the second delivery pipeline.

12. The satellite assembly in accordance with claim 10, wherein said control means includes a throttle valve member operatively connected between the first reservoir and said expander and shaft.

13. The satellite assembly in accordance with claim 10, wherein the capacity of said satellite assembly is 1000 megawatts or less.

14. The satellite assembly in accordance with claim 10, wherein the capacity of said satellite assembly is between about 1 to 10 megawatts.

15. The satellite assembly in accordance with claim 12, wherein said control means further includes a pressure measurement and control member to measure the pressure of the gas exiting the first reservoir.

16. The satellite assembly in accordance with claim 10, wherein the pressure of the gas exiting said expander is at least 15 psi.

17. The satellite assembly in accordance with claim 10, wherein said control means includes a pressure reducing

valve operatively connected to an input of high pressure intermediate to the expander of said satellite assembly.

18. The satellite assembly in accordance with claim 17, wherein said control means distributes the operation of the pressure reducing valve and the control valve at the high pressure inlet of said expander.

19. The satellite assembly in accordance with claim 17, wherein the control valve of said expander is connected between the exit of the expander and the low pressure line.

20. The satellite assembly in accordance with claim 10, wherein said control means includes a throttle valve member operatively connected between said expander and shaft and the secondary delivery pipelines.

21. The satellite assembly in accordance with claim 10, wherein said gas is air and wherein the satellite assembly includes at least one burner at the input to said expander.

22. The satellite assembly in accordance with claim 21, wherein said sources of compressed air and compress gas are provided either by the gas distribution network or by a separate source.

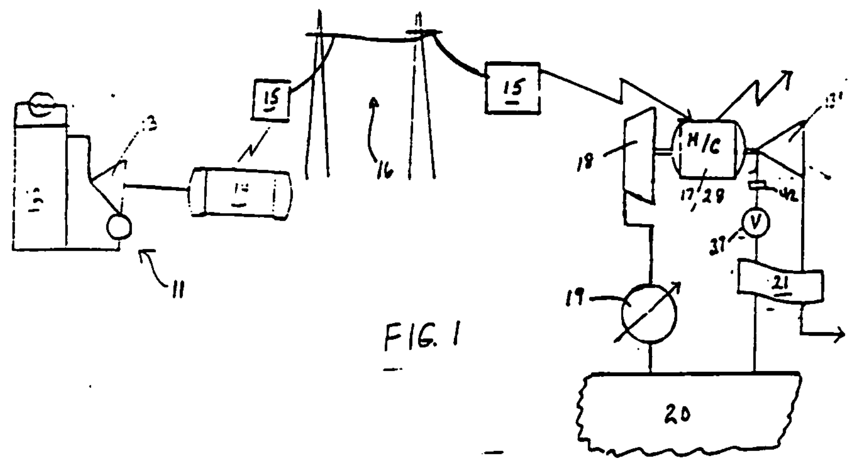


FIG. 1

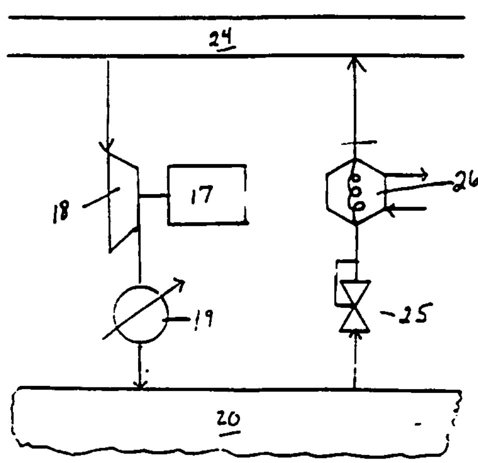


FIG. 2

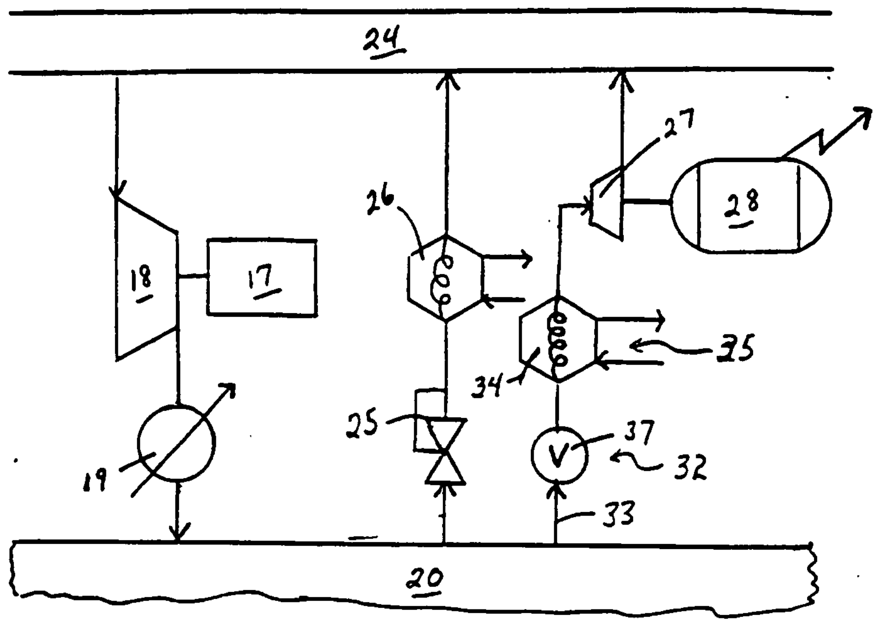


FIG. 3

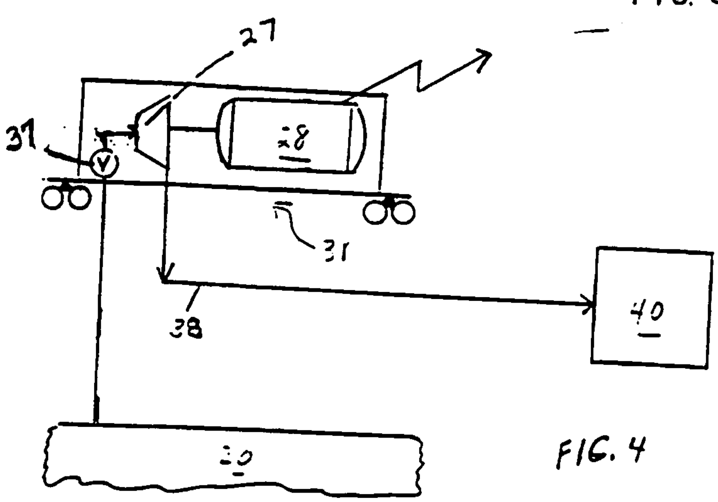


FIG. 4

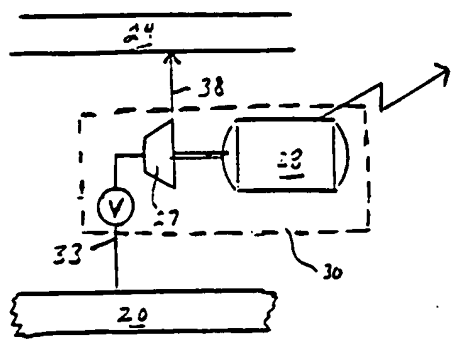


FIG. 5

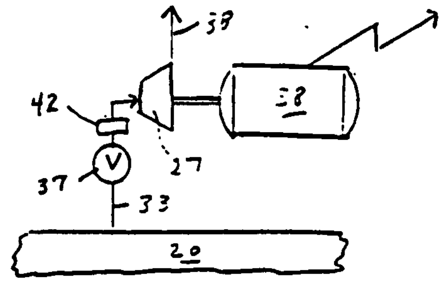


FIG. 6

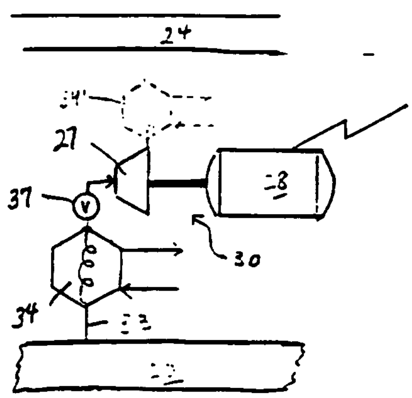


FIG. 7

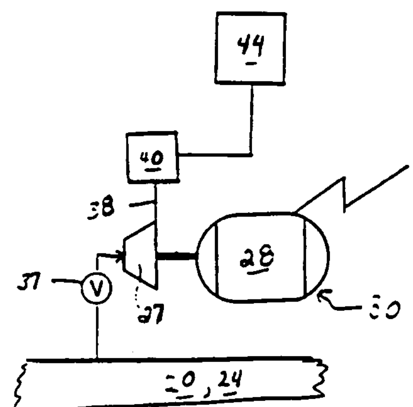


FIG. 8

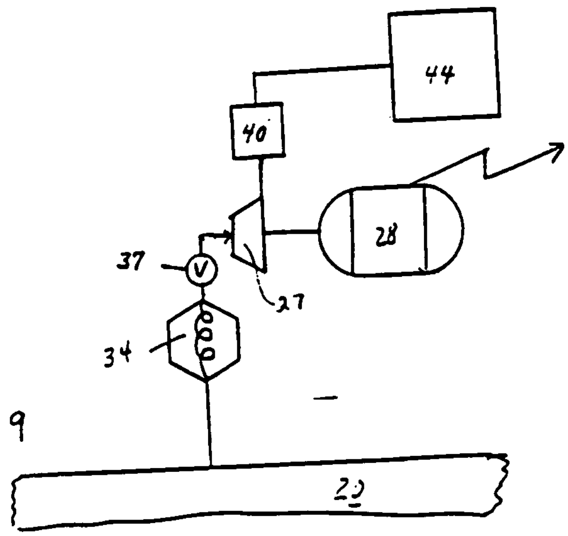


FIG. 9

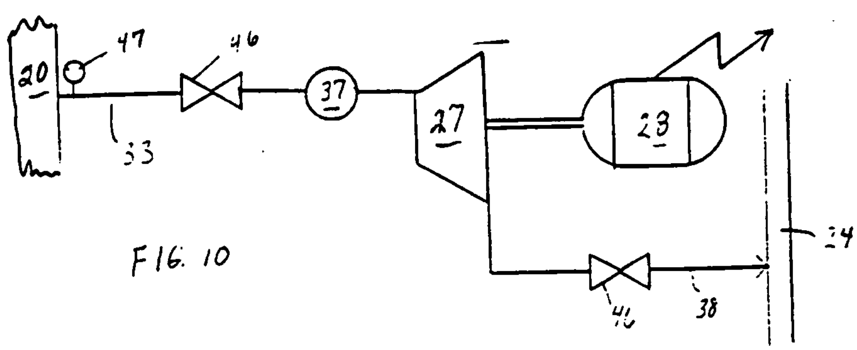


FIG. 10

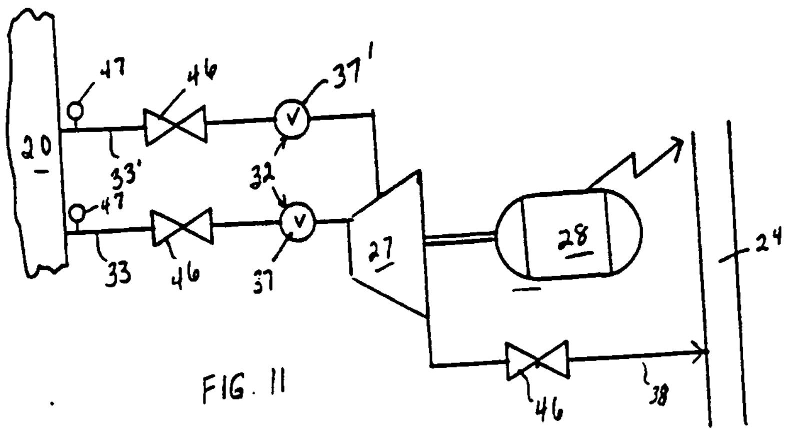

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FIG. 11

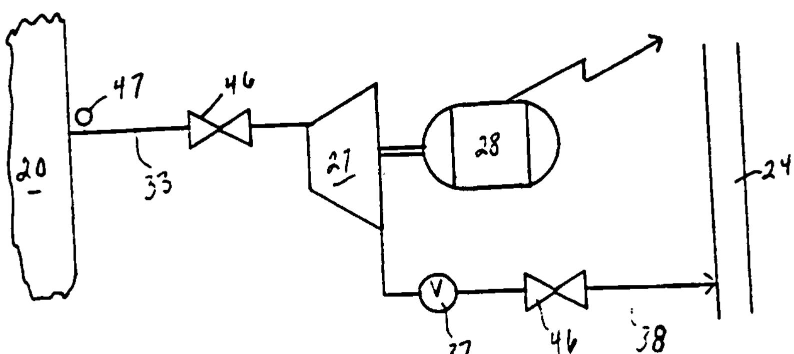
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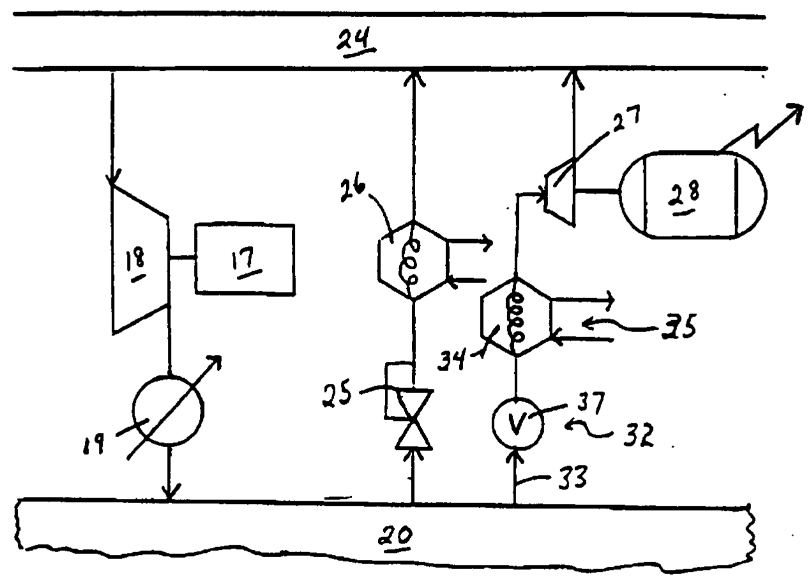
FIG. 12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